JIM

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PILOT PLANT TECHNICAL BRIEFING

The world's tar sand deposits appear to be divided into two basic types characterized by the way in which the tar and sand are associated within the ore structure. In the first, the tar or bitumen in the ore is separated from the silica sand grains by a film of water. These sands are designated "water wet" and are typified by the large deposits in the Athabasca region of Canada.

The other type is the so-called "oil wet" sand in which the bitumen is bonded directly to the sand grains with little or no water present. Much of the tar sand found in the United States, particularly in Utah where 90% of the country's known reserves are located, is of the "oil wet" type. Figure 1 shows a photomicrograph of typical oil wet tar sands. One can see from the photograph the variation of sand size within the ore. Most ores contain less than 5% of this fine material. It appears that most of the fine particles are Alpha Quartz, similar in composition to the larger sand particles and not clay minerals typically associated with the Canadian "water wet" ores.

The bitumen associated with the Utah "oil wet" tar sands is also much more viscous, in some cases by several orders of magnitude, than the bitumen found in Canadian tar sands. Some Utah bitumen also can contain an order of magnitude less sulfur than the Canadian bitumen.

A processing strategy for separation of bitumen from "water wet" tar sand ore was successfully worked out by the early Canadian researchers, and the so-called "Clark" hot water process has been successfully applied to two large commercial plants now operating in Canada. However, heretofore, the Clark Process and its variations have not been successful in processing "oil wet" tar sands ores.

A research team at the University of Utah headed by Drs. Alex Oblad and Jan Miller has developed a complete package of processing strategies for the separation of bitumen from these "oil wet" sands. The principal work has been previously reported in the literature (Misra and Miller, 1980, Sepulveda, et al, 1977; Sepulveda and Miller, 1978; Sepulveda, 1977.)

The University of Utah process, as licensed by Enercor, is a hot water-alkali assisted process similar in principle to the Canadian technique but approached from a mineral dressing point of view and hence employing much different specific processing steps. The complete process to produce a clean bitumen consists of the following four steps:

1. A hot water, alkali assisted, high shear, tar sand conditioning step wherein the bitumen is physically and chemically disengaged from the associated sand.
2. A classical air flotation step where the bitumen and some fine sand are separated by air bubbles from the water-sand alkali slurry under high recovery conditions.

3. A sand hot water separation wherein the sand slurry from the above flotation step is processed in cyclones, vacuum filters, and settling tanks in order to obtain a recycle solution for use in step (1) and (2) processing and a clean, damp sand for disposal. A flocculating agent is added to the slurry appropriately to increase sandliquid separation rates.
4. A crude bitumen upgrading step in which the crude bitumen from step (2) is mixed with a hydrocarbon solvent such as naphtha or gas oil for the purpose of reducing the hydrocarbon viscosity and density and allowing the remaining water and sand associated with the crude bitumen to be separated. The solvent is then easily separated from the bitumen by distillation and recycled.

Enercor has the exclusive rights to this technology under license from the University of Utah for the purpose of using the process to process its own extensive ore reserves and sublicensing the technology to other interested companies.

A pilot plant using the University of Utah data has been designed, constructed, and operated by Enercor and the State of Utah in Salt Lake City for the purpose of demonstrating the above process on a continuous basis and at an anticipated processing rate of 125 tons per day of ore feed rate. Depending on ore grade, approximately 50 to 100 barrels per day of bitumen product will be produced. A simplified flow sheet for the process is shown in Figure 2.

Ore from the pilot plant was mined on a campaign basis, hauled to the pilot plant site, and crushed ready for processing.

The ore is fed into the process from the storage pile via a front end loader, feed hopper, weigh feeder, and conveyor belt. A lump breaker is installed in the feed bin to break up any reconsolidated material formed after crushing.

The conditioning step uses two attrition mixers in series to provide the high shear mixing atmosphere for proper bitumen-sand disengagement. The hot, thick pulp from this equipment flows by gravity to a four-cell air flotation tank. Additional hotwater solution is added to the pulp as it enters the flotation equipment to provide the proper solids concentration.

Crude bitumen is skimmed off the top of the flotation cell and is pumped forward in the process. A moyno pump is used to handle this bitumen-sand-water concentrate.

The sand slurry from the flotation cell underflow is pumped to a cyclone where the coarse sand material leaves the bottom of the cyclone to a horizontal belt vacuum filter. The cyclone overflow flows to a gravity thickner for further settling of the fine sand. Thickner underflow also goes to the filter and is placed on the belt after the cyclone discharge. A clear thickner overflow flows to a surge tank and is recycled to the conditioning and flotation equipment. All streams are flocculated appropriately.

The sand on the filter is washed with makeup water to remove alkali, air dried, and discharged from the filter via a conveyor to waste.

Soda ash and caustic soda have been chosen as the pilot plant alkali and a polyalcohol as the flocculating agent. The temperature in the conditioning step is maintained at 190° to $200^{\circ}F$ via recycle solution heat exchange.

The crude bitumen concentrate from flotation is pumped to a mix vessel into which coker naphtha or gas oil is added as a solvent. The solvent-crude bitumen mix overflows to a settler tank where the majority of the solids and water are removed as an underflow and sent to the filter. Final cleaning of the organic overflow phase is accomplished in a special propietary unit. The clean bitumen-solvent is then steam stripped in a distillation column. The hot bitumen product is sent to storage. The solvent steam overhead is air condensed, the solvent recycled, and the condensed steam used as sand vacuum filter wash.

Figures 3, 4, 5, and 6 are photographs of the pilot plant showing the equipment as described.

Ten thousand tons of tar sand ore from five or six of Utah's deposits are being processed in the pilot plant. These include ore from North P. R. Spring, White Rocks, South P. R. Spring, Asphalt Ridge, Sunnyside, and Tar Sand Triangle as shown in Figure 7.

The ores processed have the following general characteristics as shown in Figure 8.

By varying processing conditions slightly to accommodate different bitumen viscosities, typically 95% of the bitumen present in the ore is removed as a concentrate from the flotation cells.

The sand discharged from the vacuum filter contains 8-12% by weight water, a slight amount of residual bitumen, and a trace of soda ash. The concentrate from the flotation cells contains on the average 50% bitumen, 25% water, and 25% sand. After solvent treatment, the semi-clean bitumen contains approximately 7% water and 3% sand, and the final clean bitumen contains less than 0.4% water and 0.1% sand.

Various processes are available for upgrading the bitumen into a synthetic crude oil feedstock suitable for conventional oil refinery processing into transportation fuels.

The bitumen produced in the pilot plant has been subjected to delayed coking analysis. Using conventional delayed coking technology similar to that applied in a modern oil refinery to vacuum column bottoms, an upgraded very high quality synthetic crude oil suitable for refinery hydrotreating, cat-cracking, and reforming to transportation fuels, can be made. A typical analysis of this synthetic crude oil is shown in Figure 9.

The pilot plant and coking results have been translated into a typical commercial synthetic crude oil product processing plant composed of one 5,000 BPD process demonstration module. Such a plant could be expandable to any capacity by adding additional 5,000 BPD modules as required.

This mine mouth plant has been designed to be located at North P. R. Spring in Eastern Utah at a location designated as Rainbow. Tar sand ore from nearby deposits would be surface mined using truck and shovel methods with minimal blasting of overburden and tar sand ore required. R.O.M. ore would be hauled to the plant for processing. Spent, wet, clean sand would be returned to the mine for land reclamation along with overburden and top soil. Total plant water use for this 5,000 BPD project is estimated at 5,000 acre-feet per year and is piped to the project from a nearby source on the White River. Product would be transported to local oil refineries by tank truck.

The plant would be designed to comply with all environmental and safety guidelines using the best available technology.

The coke produced in the delayed coking unit contains low ash and sulfur and is burned to produce steam for plant usage. Any surplus coke can be sold. Sour gas is burned for process fuel.

The plant was designed for the typical Rainbow ore of 10 weight percent bitumen and an overall plant volume recovery of 75%.

A flow sheet of the plant is shown in Figure 10.

The investment for the 5,000 BPD demonstration plant module and sufficient mining equipment for supplying ore to the plant and reclaiming spent sand overburden is expected to be less than $100 million. The estimated plant operating cost is less than $22 per barrel of synthetic crude oil.

Figure 1: Typical Oil Wet Tar Sands

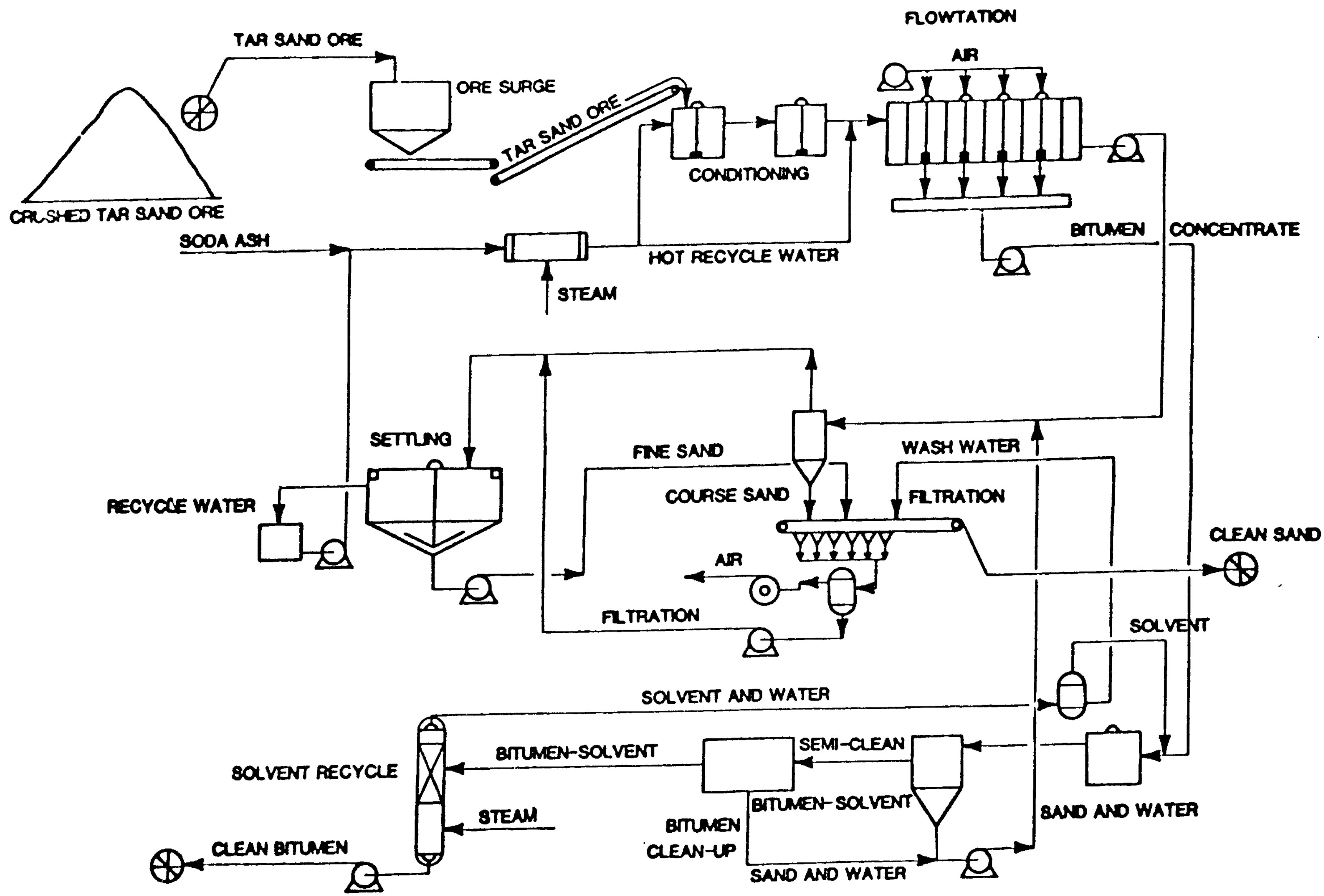


FIGURE 2. TAR SAND PILOT PLANT PROCESSING SCHEME

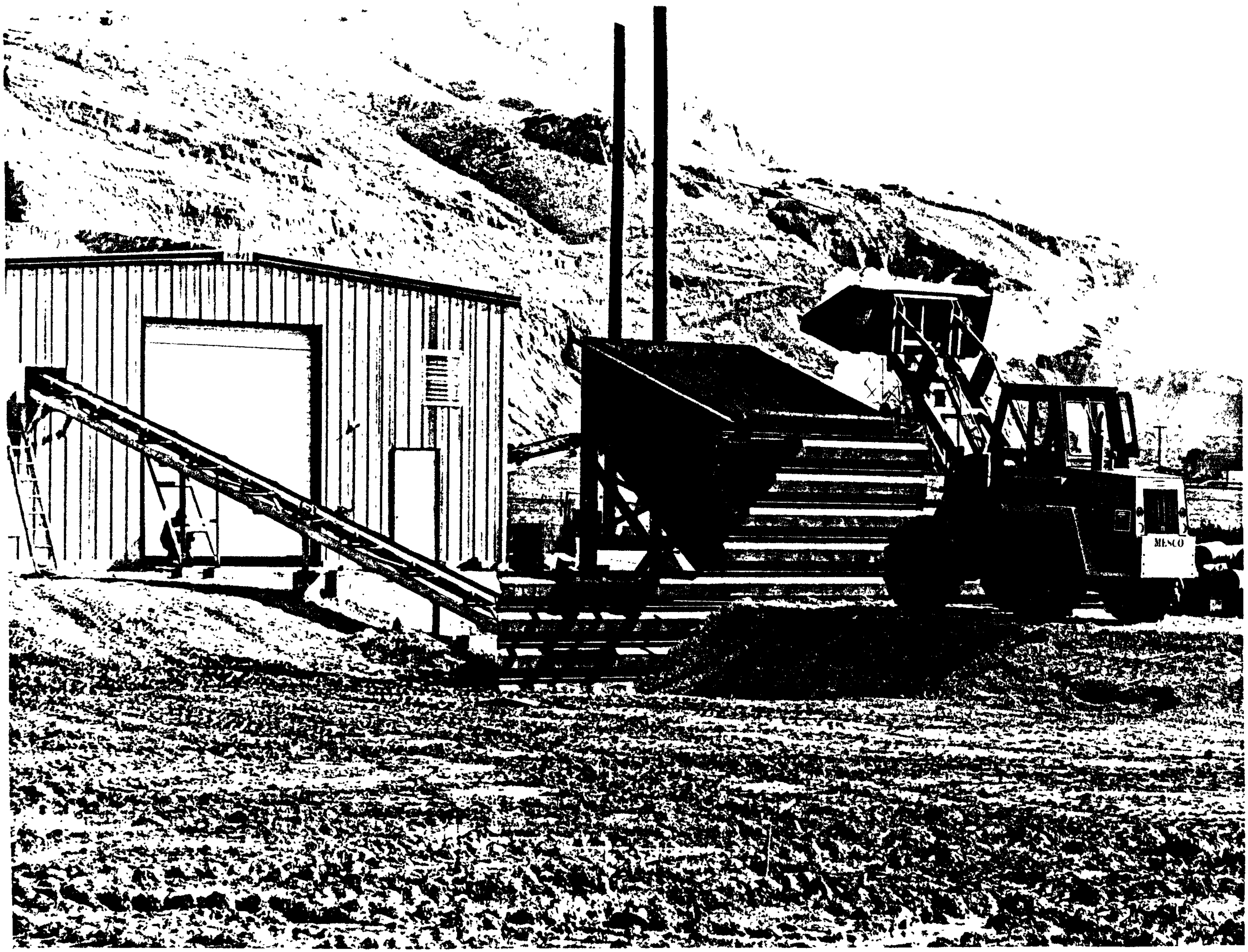


Figure 3: Ore Feed System

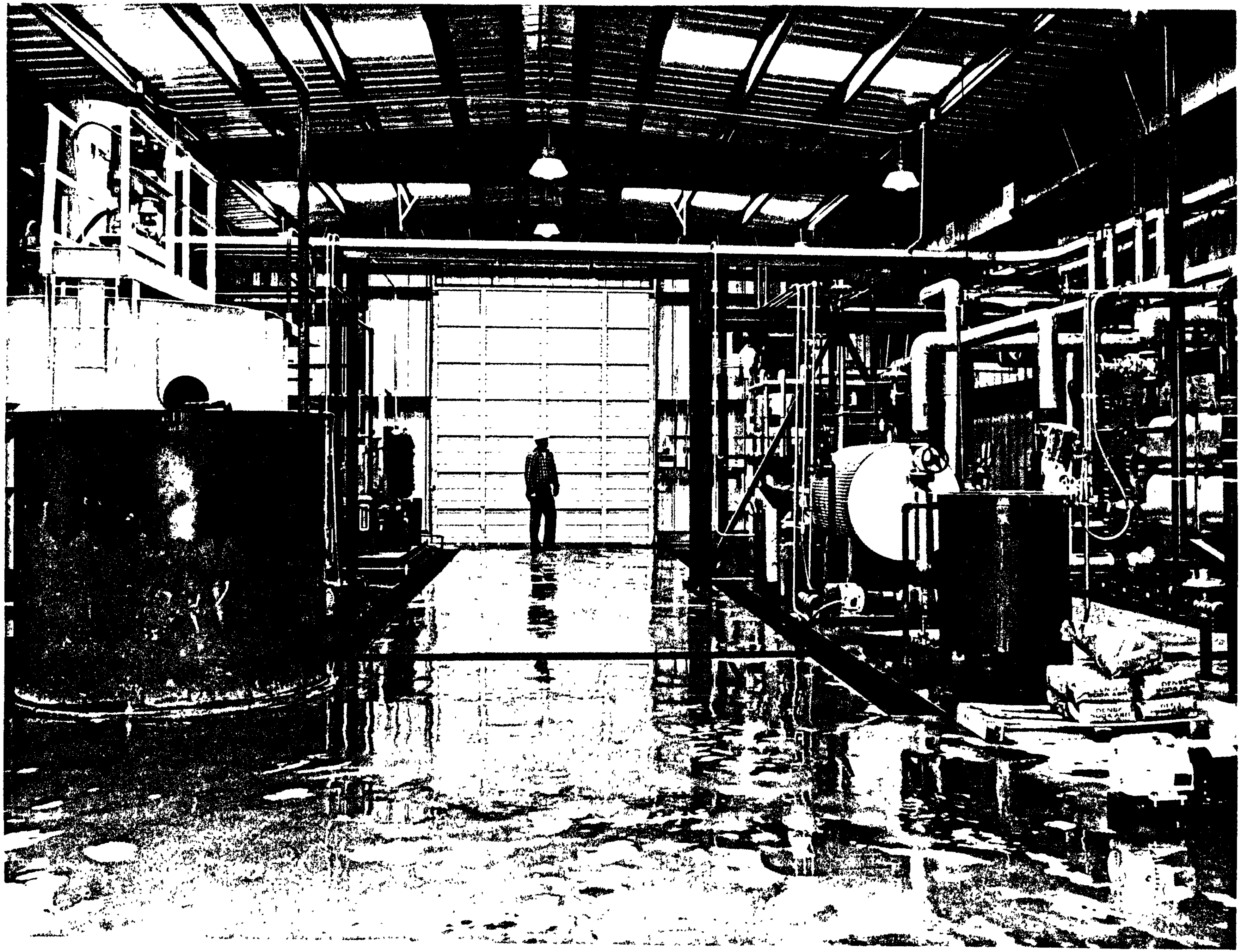


Figure 4: Inside Pilot Plant Building

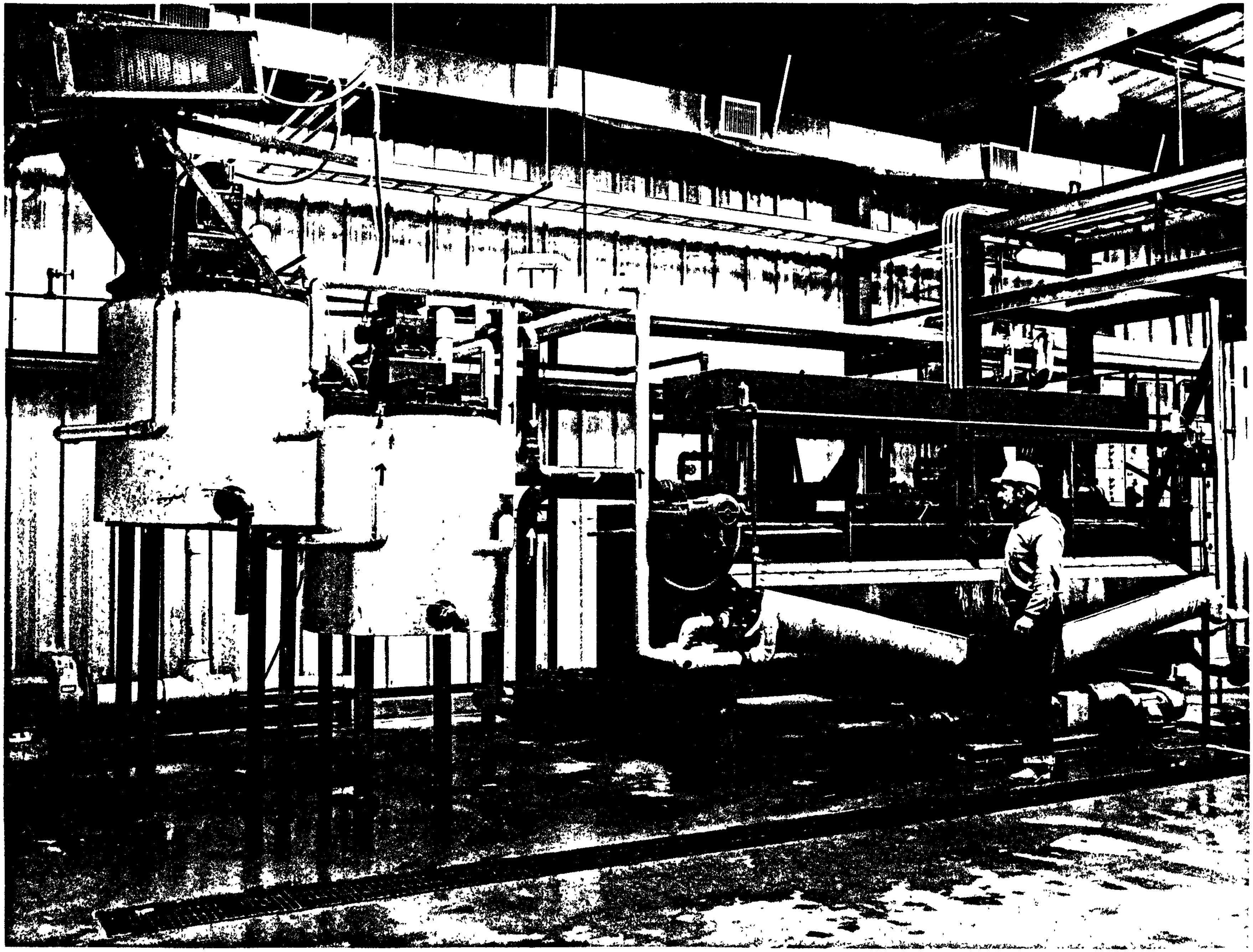


Figure 5: Conditioning and Flotation

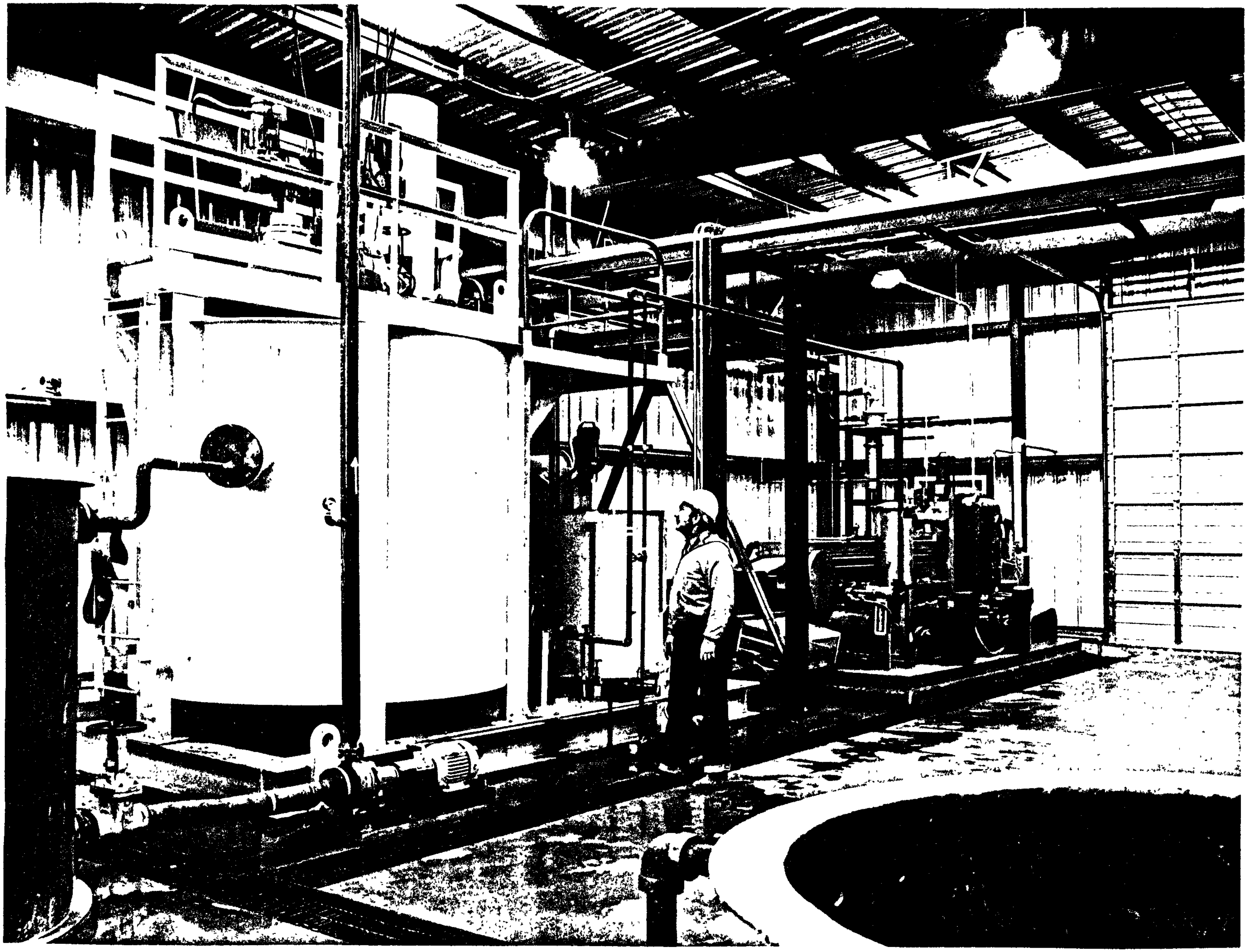


Figure 6: Settling and Flocculation

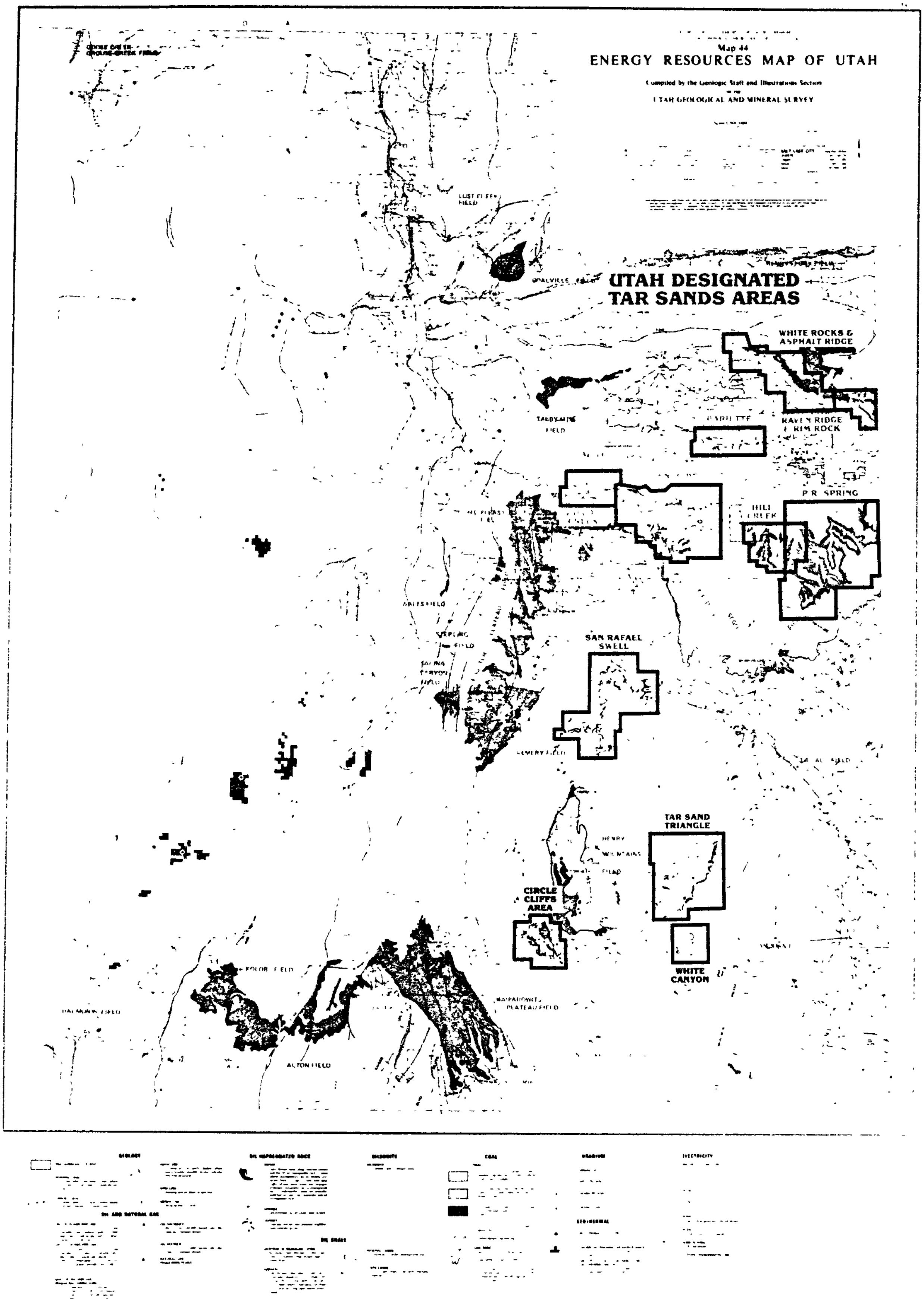


Figure 7: Tar Sand Deposits of Utah

Figure 8

BITUMEN PROPERTIES OF UTAH TAR SAND ORES

Weight Percent Bitumen in the Ore	4-12%
Bitumen Density	9°-11° API
Bitumen Viscosity Poise at $70^{\circ}F$	10^4-10^7
Weight Percent Sulfur	0.3-0.5%
Weight Percent Nitrogen	0.9-1.0%
Nickel	25 PPM
Vanadium	120 PPM
Average Molecular Weight	600-800
Carbon/Hydrogen Atomic Ratio	0.60-0.65
Volatiles at $530^{\circ}F$	50%
Atmospheric Cracking Temperature	$925^{\circ}F$

Figure 9

SYNTHETIC CRUDE OIL PRODUCED FROM DELAYED COKING OF TAR SAND BITUMEN

Feed Information

6050 BPD
9.2° API
17.2 wt % Con-Carbon
0.57 wt % Sulfur

Coker Yields

	Syncrude BPD	Wt %
H_2S	--	0.1
H_2-C_2	--	4.5
C_3	306	2.6
C_4	210	2.0
C_5-400°F	1265	15.8
Gas Oil	3219	47.5
Coke	--	27.5
	5000	100.0

Product Properties

	C_5-400°F	
Gravity		54.5° API
Sulfur		0.1 wt %
Octane	62 Res Cl	77.8+3cc

Pona

P	43.8	vol %
O	34.7	vol %
N	11.0	vol %
A	10.5	vol %

Gas Oil

Gravity	26.4 API
Sulfur	0.38%
E. P.	920°F

Coke

Density	55 lbs/ft^3
Sulfur	0.88%

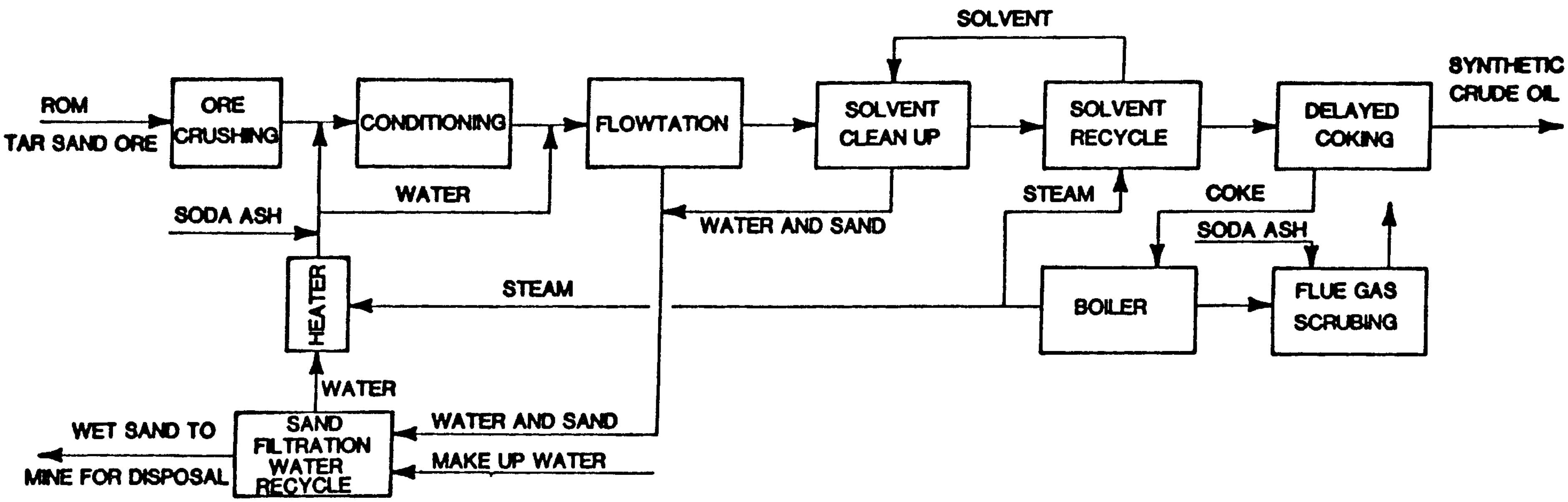


FIGURE 10. 5000 BPD SYNTHETIC CRUDE OIL FROM TAR SAND PROCESSING SCHEME

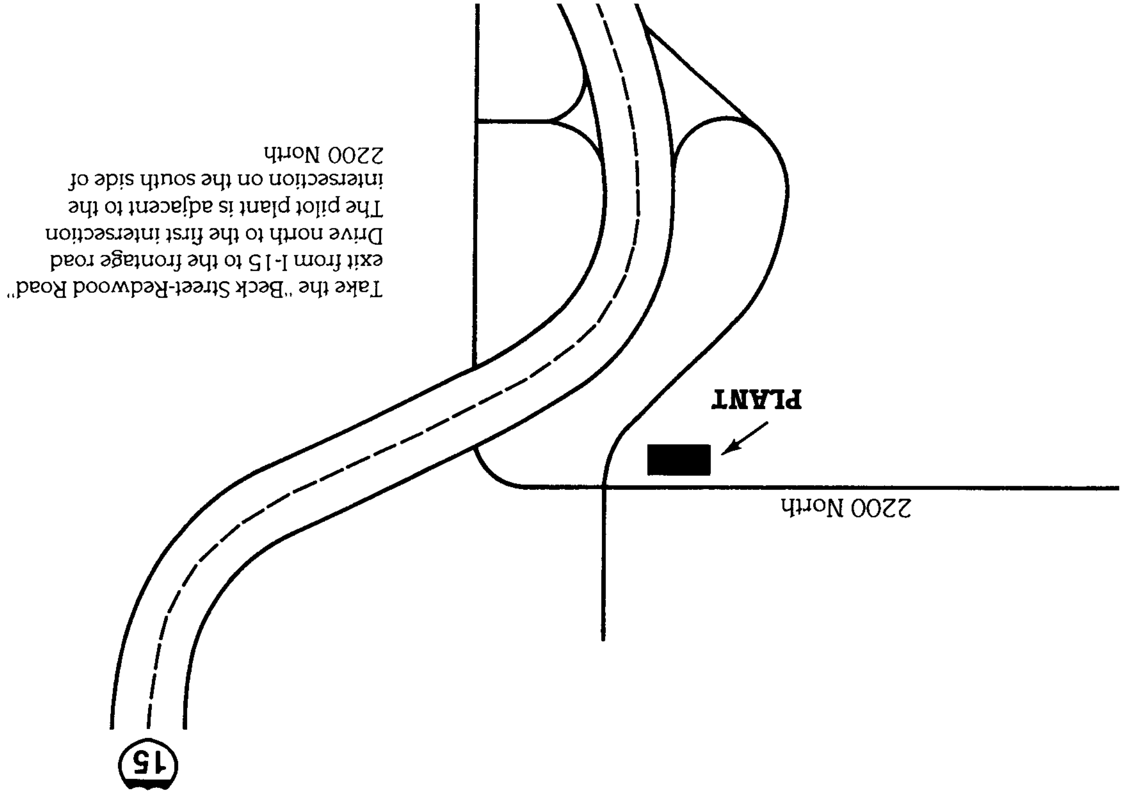
Responsible State Agency: State Advisory Council on Science and Technology
Prime Contractor: Enercor
Plant Design and Construction: Ford, Bacon, and Davis, Utah
Plant Operation: University of Utah Research Institute
Project Monitor: Utah Engineering Experiment Station

The State Advisory Council
on Science and Technology and Enercor
invite you to an open house and informal technical briefing
on the operation of the recently completed
State of Utah Tar Sands Pilot Plant.

This facility is the first of a kind for the recovery
of the vast tar sands synfuel resources
in the state of Utah.

November 9, 1981
8:30 a.m.
North Salt Lake
(see map on back)

For further information, call Utah Engineering Experiment Station, 581-6348.



An invitation to join

the Honorable Scott M. Matheson

for a ribbon-cutting ceremony at the

State of Utah Tar Sands Pilot Plant